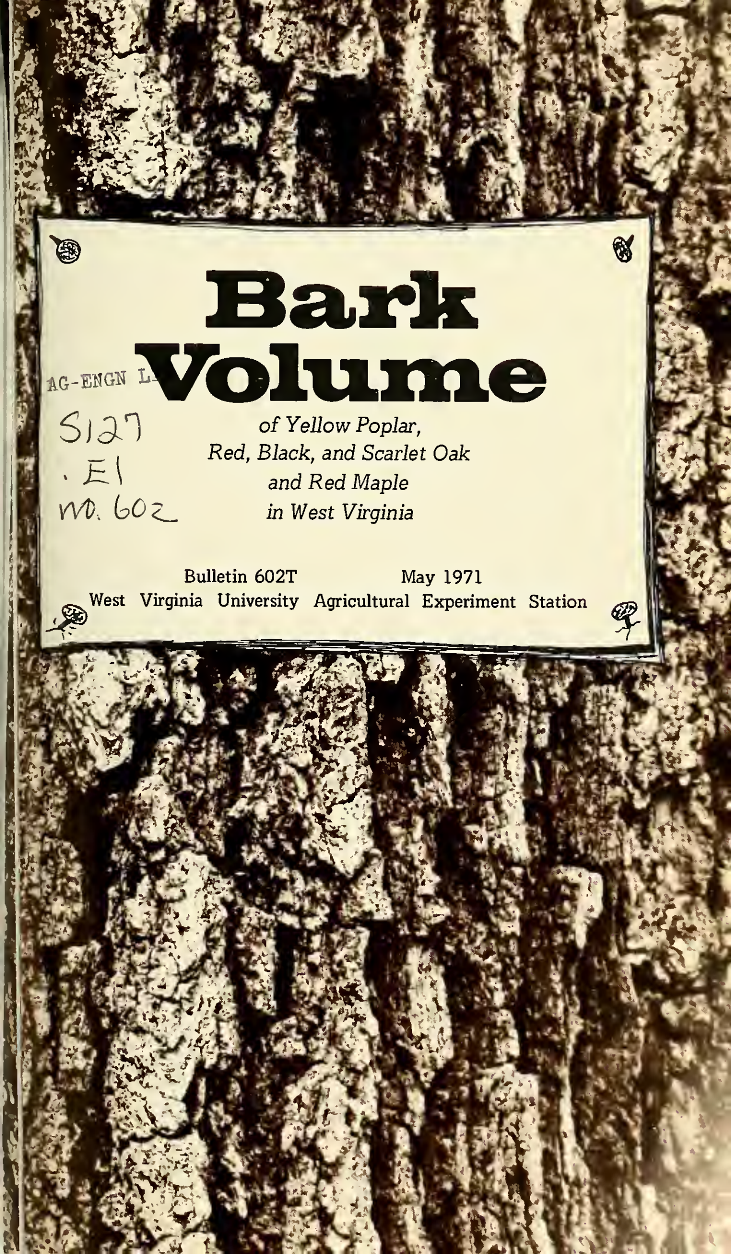

# Bark Volume

*of Yellow Poplar,*
*Red, Black, and Scarlet Oak*
*and Red Maple*
*in West Virginia*



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# ark Volume of Yellow-Poplar, Red, Black, nd Scarlet Oak, and Red Maple in orthern West Virginia*

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UTILIZATION of bark presents a major problem in the more complete use of forest products. The bark removed annually in the pro- ction of lumber, pulp and other wood products exceeds 20 million tons. ly a small percentage of this is utilized for fuel, mulch and a few other s. The remainder must be disposed of, frequently at a financial loss.

Considerable attention has been focused recently on more efficient lization and disposal of bark. In order to expedite this effort, addi- al information is needed concerning the volume of bark actually avail- e in standing trees of different species and sizes. This report deals with k volumes of standing trees of several commercially important hard- od species. Variation in bark volume within and between trees is also sidered.

## erature Review

Information relating specifically to bark volume has been obtained narily by mensurationists. They have found that, at least for some ies, the ratio of diameter-inside-bark or bark thickness to diameter-out- -bark at a particular height is approximately constant. Thus, at the ific height investigated (usually at breast height), bark volume, ex- sed as a percentage of total volume, is unaffected by diameter. Linear ations relating bark thickness to diameter-outside-bark for a number of pecies are summarized by Spalt and Reifsnyder (7).[1] They also pre- values for bark thickness expressed as a percentage of d.b.h. Assum- a constant relationship between variables, such values may be used to nate bark volume percentages. *The Forestry Handbook* (6, Section 1, p.) provides bark thickness values for trees of different diameters for

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Numbers in parenthesis refer to literature cited.

several hardwood and softwood species. The same publication (Section pp. 3-5) gives bark volume expressed as a percentage of total cubic fo volume for a number of species. In some species, percentage bark volu (based on measurements at breast height) tends to decrease as diame and/or age increases (2,4,5).

The ratio of bark thickness to diameter other than at breast heig has received little attention. Pemberton (5) found that the ratio vari inversely with height in redwood. Miller (3) reports a curvilinear crease in bark thickness with increasing height for slash pine.

Probably because of the limited commercial value of bark, bark v ume tables have been prepared for only a few species. *The Forestry Ha book* (6, Section 1, p. 5) presents a cubic foot volume table for the b of eastern hemlock. Warner and Goebel (8) have prepared bark volu tables for several species of southern pine.

Perhaps the greatest lack of information regarding volume is effect of height within d.b.h. classes and the effect of diameter at ot than breast height. Such information is important because bolts of eq diameter may occur at varying heights, depending on size of trees.

## Description of Study Areas

Two study areas in northern West Virginia were used for this inve gation. They will be referred to as the Coopers Rock and Tygart Va areas.

Five species, red oak (*Quercus rubra L.*), black oak (*Quercus v tina* Lam.), scarlet oak (*Quercus coccinea* Muenchh.), yellow-pop (*Liriodendron tulipifera* L.) and red maple (*Acer rubrum* L.) w sampled on the Coopers Rock area. This area is part of the West Virg University Forest located in Preston County, West Virginia at an el tion of about 2,500 feet above sea level.

It was heavily cut over about 50 years ago, subsequently burned. is now stocked with essentially even-aged stands, mainly of sprout orig The site on which the yellow-poplar trees were located has an easte exposure and a moderate slope. The average age of the largest tre of this species sampled (14-16 inches d.b.h.) was 37 years based on a ring count at stump height. The site on which the red oak, black oak and sc let oak trees were located is at a slightly higher elevation and h a north exposure. The average age of the largest trees sampled (14-16 inch es d.b.h.) was 51 years.

Two species, red oak and yellow-poplar were investigated on the Tygart Valley area. This tract is located near Dailey in Randolph County,

West Virginia. The area is currently under the management of the Division of Forestry of West Virginia University. The yellow-poplar trees investigated were located at an elevation of about 2,300 feet above sea level on a northeast-facing slope. The average age of the sample trees 14-16 inches d.b.h. was 58 years. The site on which the red oak sample trees were located is about 2,500 feet above sea level and has a southwestern exposure. The average age of the trees 14-16 inches d.b.h. was 53 years.

## Relationship of Bark Volume to Stem Diameter and Bark Thickness

The volume of bark contained in a section of a stem is dependent on the average total diameter outside bark (D), the average bark thickness (t) and the length of the section ($l$). Total volume of wood and bark may be expressed as $V_T = \pi D^2 \, l/4$. The volume of the wood will equal $\pi d^2 \, l/4$ where d is diameter inside bark or $d = D - 2t$. The bark volume, $V_B$, will therefore equal the difference between the two or $\pi \, l/4 \, (D^2 - d^2)$. The ratio of bark volume to total volume may be expressed as $V_B/V_T = 1 - \left(\frac{d}{D}\right)^2$. If total volume is known, actual bark volume may be computed as $V_B = V_T \left[ 1 - \left(\frac{d}{D}\right)^2 \right]$. Meyer (1) has shown that the average of a number of observations of d/D may be most accurately obtained by computing a ratio of sums as $\Sigma d/\Sigma D$.

The theoretical relationship between bark volume, expressed as a percentage of total volume, and d/D is shown graphically in Figure 1. It should be noted that while the relationship is curvilinear, an assumption of linearity will produce an error of little practical significance within the range of d/D values normally encountered.

The ratio d/D is generally considered constant for a particular species since when values of d at breast height are plotted over corresponding values of D, a straight line passing through or nearly through the origin results. For some species, the ratio is not constant but increases with increasing d.b.h. Whether or not a linear relationship between d and D exists as height increases within trees has not been investigated. Variation in d/D at a specific height in trees of different diameters has also received little attention.

Part of this report deals with variation in d/D (or $V_B/V_T$) of red oak, scarlet oak, black oak, yellow-poplar and red maple trees with height within trees and with diameter between trees at given heights.

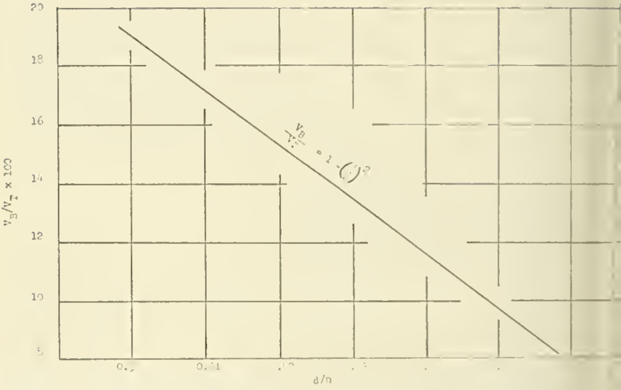


**Figure 1. Theoretical relationship between per cent bark volume and d/D.**

# Bark Volumes to a Four-Inch Top of Yellow-Poplar and Red Oak

In the following section, equations and tables for estimating cu foot bark volume of yellow-poplar and red oak are presented. The i mation should be applicable for most sites in northern West Virgin

## COLLECTION OF DATA

At each location (Coopers Rock and Tygart Valley), a minimu ten yellow-poplar and ten red oak trees were randomly selected for pling in each of six d.b.h. classes (4-6 inches, 6-8 inches, 8-10 inches, inches, 12-14 inches, and 14-16 inches). For each tree sampled, dia outside bark (D) was measured to the nearest 0.1 inch with a dia tape at 1.5 feet above the ground, 4.5 feet above the ground, and a sequent 6-foot intervals to a 4-inch top. Bark thickness (t) was mea with a Swedish bark gauge to the nearest 0.05 inch at two diamet opposite sides of the stem at the same heights.

The total volume of each stem section was computed by the Sm formula. Bark volume of each section was computed by the fo

$$V_B = V_T \left[ 1 - \left(\frac{d}{D}\right)^2 \right]$$ as derived previously. Total bark volume o ach

tree was obtained by summation of volumes of individual sections.

# evelopment of Estimating Equations and Bark Volume Tables

Graphic plotting of both total volume and bark volume against the juare of the diameter breast high ($D^2$) and against height to a four-inch op indicated essentially linear relationships for both species investigated. or this reason, bark volume was related to tree size for each species on ach location by least squares solutions of equations of the form = a + b X where $X = D^2H/10$, *a* is a constant and *b* is the slope of ie regression. The estimating equations are shown below:

**Red Oak**

| | |
|---|---|
| Coopers Rock | $V = 0.367 + 0.00400\ (D^2H/10)$ **[2] |
| Tygart Valley | $V = 0.359 + 0.00425\ (D^2H/10)$ ** |
| Combined | $V = 0.353 + 0.00417\ (D^2H/10)$ ** $r = 0.95768$ |

**Yellow-poplar**

| | |
|---|---|
| Coopers Rock | $V = 0.364 + 0.00489\ (D^2H/10)$ ** |
| Tygart Valley | $V = 0.355 + 0.00588\ (D^2H/10)$ ** |
| Combined | $V = 0.359 + 0.00547\ (D^2H/10)$ ** $r = 0.95693$ |

No significant difference was found between regression coefficients r red oak at the two locations. For yellow-poplar, the regression coeffi- ent for trees at Tygart Valley was significantly greater than that for es at Coopers Rock. From a practical standpoint, however, the use of e equation based on combined observations seems justified. The esti- ated bark volumes of trees with $D^2H/10$ values of 2,000 or less, as esti- ated by the equation based on combined observations, will be within per cent of those obtained by use of either of the other equations.

Bark volumes as computed from the bark volume equations are own in Table 1 and 2.

# riation in Per Cent Bark Volume thin and Between Trees

The ratio of bark volume to total volume of a bolt or log may be ex- ssed as

$$\frac{V_B}{V_T} = \left[1 - \left(\frac{d}{D}\right)^2\right]$$

ere d and D are average diameters inside and outside bark, respective- l As bark thickness increases in relation to outside diameter, the ratio

[2]Significant at the 1 per cent level.

## TABLE 1
## Cubic foot bark volume of yellow-poplar.

| D.b.h. (inches) | Height to a four-inch top (feet) 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 | 110 | Basis (No of trees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.0 | .45 | .49 | .53 | .58 | .62 | .66 | .71 | | | | | | | | | | | | | | | 1 |
| 4.5 | .47 | .52 | .58 | .64 | .69 | .75 | .80 | .86 | | | | | | | | | | | | | | 3 |
| 5.0 | .50 | .56 | .63 | .70 | .77 | .84 | .91 | .98 | 1.04 | | | | | | | | | | | | | 9 |
| 5.5 | | .61 | .69 | .77 | .86 | .94 | 1.02 | 1.10 | 1.19 | 1.27 | | | | | | | | | | | | 11 |
| 6.0 | | .65 | .75 | .85 | .95 | 1.05 | 1.15 | 1.24 | 1.34 | 1.44 | 1.54 | | | | | | | | | | | 12 |
| 6.5 | | .71 | .82 | .91 | 1.05 | 1.17 | 1.28 | 1.40 | 1.52 | 1.63 | 1.75 | 1.86 | | | | | | | | | | 8 |
| 7.0 | | .76 | .90 | 1.03 | 1.16 | 1.30 | 1.43 | 1.56 | 1.70 | 1.83 | 1.97 | 2.10 | | | | | | | | | | 9 |
| 7.5 | | .82 | .97 | 1.13 | 1.28 | 1.44 | 1.59 | 1.74 | 1.90 | 2.05 | 2.20 | 2.36 | 2.51 | | | | | | | | | 5 |
| 8.0 | | | 1.06 | 1.23 | 1.41 | 1.58 | 1.76 | 1.93 | 2.11 | 2.28 | 2.46 | 2.64 | 2.81 | | | | | | | | | 11 |
| 8.5 | | | 1.15 | 1.35 | 1.55 | 1.74 | 1.94 | 2.14 | 2.34 | 2.53 | 2.73 | 2.93 | 3.12 | 3.32 | | | | | | | | 6 |
| 9.0 | | | 1.24 | 1.47 | 1.69 | 1.91 | 2.13 | 2.35 | 2.57 | 2.80 | 3.02 | 3.24 | 3.46 | 3.68 | 3.90 | | | | | | | 14 |
| 9.5 | | | 1.35 | 1.59 | 1.84 | 2.09 | 2.33 | 2.58 | 2.83 | 3.07 | 3.32 | 3.57 | 3.82 | 4.06 | 4.31 | | | | | | | 9 |
| 10.0 | | | 1.45 | 1.73 | 2.00 | 2.27 | 2.55 | 2.82 | 3.09 | 3.37 | 3.64 | 3.92 | 4.19 | 4.46 | 4.71 | | | | | | | 14 |
| 10.5 | | | 1.56 | 1.87 | 2.17 | 2.47 | 2.77 | 3.07 | 3.37 | 3.68 | 3.98 | 4.28 | 4.58 | 4.88 | 5.18 | 5.48 | | | | | | 13 |
| 11.0 | | | 1.68 | 2.01 | 2.34 | 2.68 | 3.01 | 3.34 | 3.67 | 4.00 | 4.33 | 4.66 | 4.99 | 5.32 | 5.65 | 5.98 | | | | | | 12 |
| 11.5 | | | | 2.17 | 2.53 | 2.89 | 3.25 | 3.61 | 3.98 | 4.34 | 4.70 | 5.06 | 5.42 | 5.78 | 6.15 | 6.51 | 6.87 | | | | | 7 |
| 12.0 | | | | 2.33 | 2.72 | 3.12 | 3.51 | 3.90 | 4.30 | 4.69 | 5.08 | 5.48 | 5.87 | 6.27 | 6.66 | 7.05 | 7.45 | | | | | 8 |
| 12.5 | | | | 2.50 | 2.92 | 3.35 | 3.78 | 4.20 | 4.63 | 5.06 | 5.49 | 5.92 | 6.34 | 6.77 | 7.20 | 7.62 | 8.05 | 8.48 | | | | 5 |
| 13.0 | | | | 2.67 | 3.13 | 3.60 | 4.06 | 4.52 | 4.98 | 5.44 | 5.91 | 6.37 | 6.83 | 7.29 | 7.75 | 8.22 | 8.68 | 9.14 | | | | 13 |
| 13.5 | | | | | 3.35 | 3.85 | 4.35 | 4.84 | 5.34 | 5.84 | 6.34 | 6.84 | 7.34 | 7.84 | 8.33 | 8.83 | 9.33 | 9.83 | | | | 1 |
| 14.0 | | | | | 3.58 | 4.11 | 4.65 | 5.18 | 5.72 | 6.26 | 6.79 | 7.33 | 7.86 | 8.40 | 8.94 | 9.47 | 10.01 | 10.54 | 11.08 | | | 4 |
| 14.5 | | | | | | | 4.96 | 5.53 | 6.11 | 6.68 | 7.26 | 7.83 | 8.41 | 8.98 | 9.56 | 10.14 | 10.71 | 11.28 | 11.86 | 12.44 | | 6 |
| 15.0 | | | | | | | 5.28 | 5.90 | 6.51 | 7.13 | 7.74 | 8.36 | 8.97 | 9.59 | 10.20 | 10.82 | 11.44 | 12.05 | 12.67 | 13.28 | | 5 |
| 15.5 | | | | | | | 5.62 | 6.27 | 6.93 | 7.59 | 8.24 | 8.90 | 9.56 | 10.22 | 10.87 | 11.53 | 12.19 | 12.84 | 13.50 | 14.16 | 14.82 | 2 |
| 16.0 | | | | | | | 5.96 | 6.66 | 7.36 | 8.06 | 8.76 | 9.46 | 10.16 | 10.86 | 11.56 | 12.26 | 12.96 | 13.66 | 14.36 | 15.06 | 12.76 | 5 |

## TABLE 2
## Cubic foot bark volume of red oak.

| D.b.h. (inches) | Height to a four-inch top (feet) 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 | 110 | Basis (No of trees) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.0 | .42 | .45 | .49 | .52 | .55 | .59 | .62 | | | | | | | | | | | | | | | 0 |
| 4.5 | .44 | .48 | .52 | .56 | .61 | .65 | .69 | .73 | | | | | | | | | | | | | | 5 |
| 5.0 | .46 | .51 | .56 | .61 | .67 | .72 | .77 | .82 | .87 | | | | | | | | | | | | | 17 |
| 5.5 | | .54 | .60 | .67 | .73 | .80 | .86 | .92 | .98 | 1.05 | 1.11 | | | | | | | | | | | 10 |
| 6.0 | | .58 | .65 | .73 | .80 | .88 | .95 | 1.03 | 1.10 | 1.18 | 1.25 | | | | | | | | | | | 13 |
| 6.5 | | .62 | .70 | .79 | .88 | .97 | 1.06 | 1.15 | 1.23 | 1.32 | 1.41 | 1.50 | | | | | | | | | | 7 |
| 7.0 | | .66 | .76 | .86 | .97 | 1.07 | 1.17 | 1.27 | 1.38 | 1.48 | 1.58 | 1.68 | | | | | | | | | | 11 |
| 7.5 | | .70 | .82 | .94 | 1.06 | 1.17 | 1.29 | 1.41 | 1.53 | 1.64 | 1.76 | 1.88 | 2.00 | | | | | | | | | 10 |
| 8.0 | | | .89 | 1.02 | 1.15 | 1.29 | 1.42 | 1.55 | 1.69 | 1.82 | 1.95 | 2.09 | 2.22 | | | | | | | | | 14 |
| 8.5 | | | .96 | 1.11 | 1.26 | 1.41 | 1.56 | 1.71 | 1.86 | 2.01 | 2.16 | 2.31 | 2.46 | 2.61 | | | | | | | | 9 |
| 9.0 | | | 1.03 | 1.20 | 1.37 | 1.54 | 1.70 | 1.87 | 2.04 | 2.21 | 2.38 | 2.55 | 2.72 | 2.89 | 3.06 | | | | | | | 12 |
| 9.5 | | | 1.11 | 1.29 | 1.48 | 1.67 | 1.86 | 2.05 | 2.24 | 2.42 | 2.61 | 2.80 | 2.99 | 3.18 | 3.36 | | | | | | | 7 |
| 10.0 | | | 1.19 | 1.40 | 1.60 | 1.81 | 2.02 | 2.23 | 2.44 | 2.65 | 2.86 | 3.06 | 3.27 | 3.48 | 3.69 | | | | | | | 11 |
| 10.5 | | | 1.27 | 1.50 | 1.73 | 1.96 | 2.19 | 2.42 | 2.65 | 2.88 | 3.11 | 3.34 | 3.57 | 3.80 | 4.03 | 4.26 | | | | | | 6 |
| 11.0 | | | 1.36 | 1.61 | 1.87 | 2.12 | 2.37 | 2.62 | 2.88 | 3.13 | 3.38 | 3.63 | 3.88 | 4.14 | 4.39 | 4.64 | | | | | | 6 |
| 11.5 | | | | 1.73 | 2.01 | 2.28 | 2.56 | 2.84 | 3.11 | 3.39 | 3.66 | 3.94 | 4.21 | 4.49 | 4.76 | 5.04 | 5.32 | | | | | 6 |
| 12.0 | | | | 1.85 | 2.15 | 2.46 | 2.76 | 3.06 | 3.36 | 3.66 | 3.96 | 4.26 | 4.56 | 4.86 | 5.16 | 5.46 | 5.76 | | | | | 6 |
| 12.5 | | | | 1.98 | 2.31 | 2.63 | 2.96 | 3.28 | 3.61 | 3.94 | 4.26 | 4.59 | 4.91 | 5.24 | 5.56 | 5.89 | 6.22 | 6.54 | | | | 8 |
| 13.0 | | | | 2.12 | 2.47 | 2.82 | 3.17 | 3.52 | 3.88 | 4.23 | 4.58 | 4.93 | 5.29 | 5.64 | 5.99 | 6.34 | 6.70 | 7.05 | | | | 7 |
| 13.5 | | | | | 2.63 | 3.01 | 3.39 | 3.77 | 4.15 | 4.53 | 4.91 | 5.29 | 5.67 | 6.05 | 6.43 | 6.81 | 7.19 | 7.57 | | | | 6 |
| 14.0 | | | | | 2.80 | 3.21 | 3.62 | 4.03 | 4.44 | 4.85 | 5.26 | 5.67 | 6.07 | 6.48 | 6.89 | 7.30 | 7.71 | 8.12 | 8.53 | | | 7 |
| 14.5 | | | | | | | 3.86 | 4.30 | 4.74 | 5.18 | 5.61 | 6.05 | 6.49 | 6.93 | 7.37 | 7.80 | 8.24 | 8.68 | 9.12 | 9.56 | | 14 |
| 15.0 | | | | | | | 4.11 | 4.58 | 5.04 | 5.51 | 5.98 | 6.45 | 6.92 | 7.39 | 7.86 | 8.33 | 8.80 | 9.27 | 9.74 | 10.20 | | 3 |
| 15.5 | | | | | | | 4.36 | 4.86 | 5.36 | 5.86 | 6.36 | 6.86 | 7.37 | 7.87 | 8.37 | 8.87 | 9.37 | 9.87 | 10.37 | 10.87 | 11.37 | 4 |
| 16.0 | | | | | | | 4.62 | 5.16 | 5.69 | 6.22 | 6.76 | 7.29 | 7.83 | 8.36 | 8.89 | 9.43 | 9.96 | 10.49 | 11.03 | 11.56 | 12.10 | 2 |

d/D decreases, and per cent bark volume increases. If the ratio of d/T is constant within and between trees of a particular species, then per cen bark volume will also be constant. If, on the other hand, d/D varie appreciably within species, an accurate estimation of bark volume require an understanding of this variation.

The following section deals with variations in d/D (or $V_B/V_T$) o red oak, scarlet oak, black oak, yellow-poplar and red maple trees wit height-within-trees and with diameter-between-trees.

## PROCEDURE

The red oak and yellow-poplar trees sampled were the same as thos used for determination of total bark volume on the Coopers Rock are (see preceding section). In addition, five black oak, five scarlet oak, an five red maple trees were sampled in each of three d.b.h. classes (4 inches, 8-10 inches, and 12-14 inches). Values of d/D were determine for each tree at heights above ground of 1.5 feet, 4.5 feet, and at subs quent 6-foot intervals to a top diameter of approximately 4 inches.

Measurements of d and D at breast height were also made on a additional 20 yellow-poplar and red oak trees in each of six d.b.h. class (4-6 inches to 14-16 inches in 2-inch increments).

## RESULTS AND DISCUSSION

Average values of d/D for each combination of height and d.b. class for the five species investigated are presented in the Append (Tables I-V). Averages for grouped heights and d.b.h. classes are a shown. Each value for yellow-poplar and red oak is the mean of ten o servations. Values for black oak, scarlet oak, and red maple are means five observations.

Mean values of d/D and per cent bark volume based on all obser tions are compared with those based on observations at breast height Table 3. Per cent bark volume values based on measurements made breast height were greater for all species except red maple.

Red maple exhibited the lowest per cent bark volume and yell poplar the highest. Within the red oak group, black oak contained t highest per cent bark volume and scarlet oak the lowest.

### Effect of height in tree within d.b.h. classes:

The relationships between d/D and height in trees in the smallt 4-6 inch and 12-14-inch d.b.h. classes for the five species investigated a illustrated respectively in Figures 2 and 3. The results of tests of sign cance of the effect of height within all d.b.h. classes are shown in Tabl

## TABLE 3

**Average d/D values and bark volume percentages.**

| Species | d/D | | $V_B/V_T$ x 100 | |
|---|---|---|---|---|
| | Overall | At breast height | Overall | At breast height |
| \ ow-poplar | 0.912 | 0.902 | 16.8 | 18.6 |
| F l oak | 0.929 | 0.924 | 13.7 | 14.6 |
| l ck oak | 0.927 | 0.916 | 14.1 | 16.1 |
| S let oak | 0.934 | 0.927 | 13.1 | 14.1 |
| F l maple | 0.958 | 0.960 | 8.2 | 7.8 |

## TABLE 4

**l vel of significance of effect of height in tree on d/D for different d.b.h. classes.**

| »ecies | D.b.h. (in.) | | | | | |
|---|---|---|---|---|---|---|
| | 4-6 | 6-8 | 8-10 | 10-12 | 12-14 | 14-16 |
| Y ow-poplar | 1% | 1% | 1% | 1% | N.S.* | N.S. |
| R oak | 1% | 1% | N.S. | N.S. | N.S. | N.S. |
| B k oak | 5% | | 5% | | N.S. | |
| S let oak | 5% | | N.S. | | N.S. | |
| R maple | N.S. | | N.S. | | N.S. | |

*Not significant.

Height had no significant effect on the d/D ratio of red maple in a of the d.b.h. classes investigated (Table 4). On the basis of the results o his study, a d/D value of 0.96 (bark volume percentage of 8.2) would b easonable for bolts removed at any height for all d.b.h. classes. This is mewhat less than the value presented by Meyer (1) who worked with b k thickness of red maple in Pennsylvania. However, no explanation c be offered for the difference.

Above 4.5 feet, height had no significant effect on d D values of the o species within the larger d.b.h. classes (Table 4 and Figure 3). The ef ct of height was pronounced, however, in the smaller d.b.h. classes in w ch d D increased markedly with height to 16 feet (Figure 2).

In the smaller d.b.h. classes, the effect of height on d/D of yellow-p lar was pronounced (Table 4). Values of d/D increased significantly w height in all d.b.h. classes up to 12-14 inches. Within the two largest d. h. classes (12-14 inches and 14-16 inches), d/D values were essentially c tant above a height of 10 feet.

### T effect of d.b.h. on per cent bark volume at a given height:

The relationships between d/D at representative heights and d.b.h. fo ed maple, red oak and yellow-poplar are illustrated in Figure 4. The d/ values at breast height for yellow-poplar and red oak are based on

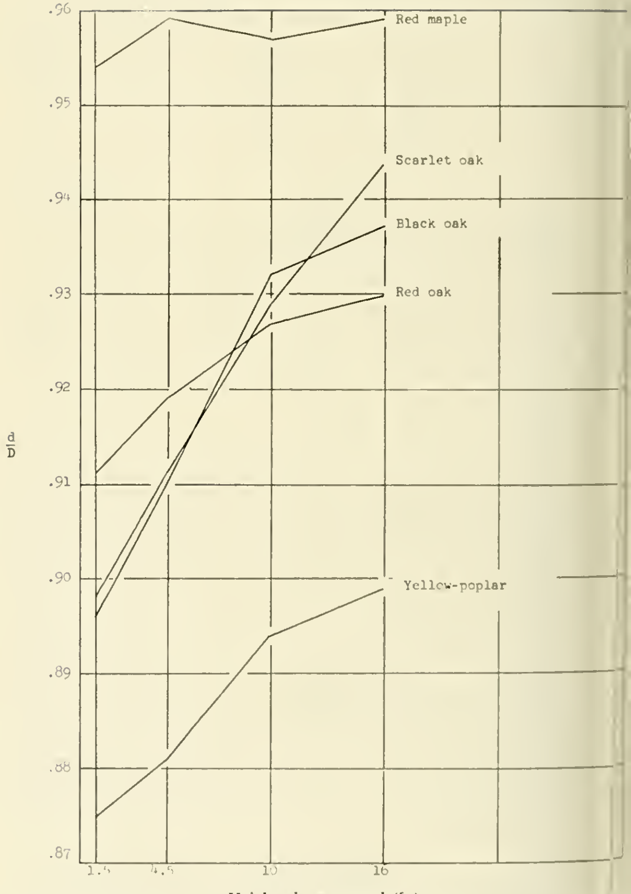


Figure 2. Relationship between d/D and height above ground of trees 4-6 inches d.b.h.


**Fi re 3. Relationship between d/D and height above ground of trees 12-14 inches d.b.h.**

3( bservations for each species. The remaining curves are plots of values sh vn in Tables I, II and V in the Appendix.

The effect of d.b.h. on d/D of red maple was statistically insignifica at all heights.

At stump height and breast height, d/D ratios of all three red oak sp ies increased significantly with d.b.h. Above breast height however, th effect in increasing d.b.h. on d/D was statistically insignificant ( ble 5).

At all heights below 28 feet, the d/D ratio of yellow-poplar increased si ificantly with increasing d.b.h., the increase being most pronounced th ugh the smaller d.b.h. classes. In the larger trees, d.b.h. had little pr tical effect on d/D at any height (Table 5).

## V ation of d/D among trees when D remains constant:

The height-in-tree from which a bolt of a given diameter is removed is pendent on the size of the tree. For example, a bolt with an average di eter (D value) of 6 inches may be taken from the base of a tree 6-8

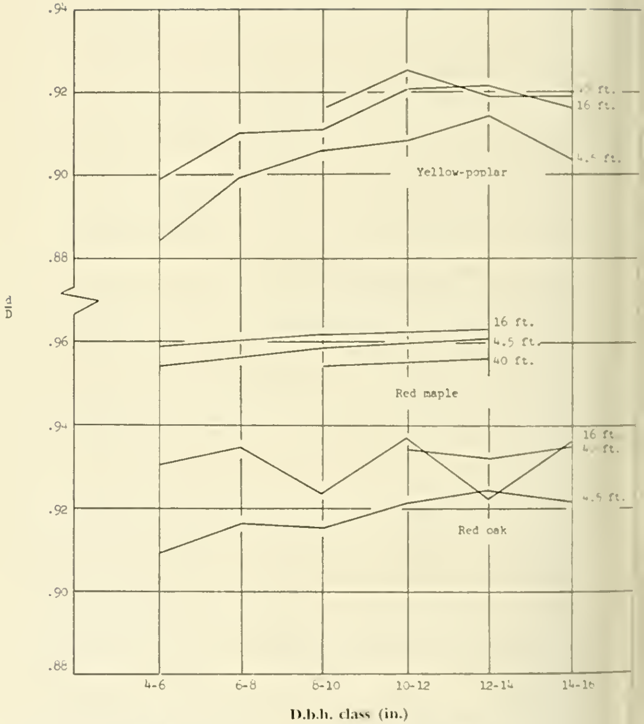


Figure 4. Relationship between d/D at representative heights and d.b.h.

## TABLE 5

### Level of significance of effect of d.b.h. on d/D at different heigh

| Species | Height above ground (ft.) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.5 | 4.5 | 10 | 16 | 22 | 28 | 34 | 40 | 46 | 52 | 58 |
| Yellow-Poplar | 1 % | 1 % | 1 % | 1 % | 5 % | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| Red oak | 5 % | 5 % | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S.* | | |
| Black oak | 1 % | 5 % | N.S. | N.S. | N.S. | N.S. | N.S. | | | | |
| Scarlet oak | 1 % | 5 % | N.S. | N.S. | N.S. | N.S. | N.S. | | | | |
| Red Maple | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | | | |

*Not significant.


**igı 5. Relationship between d/D and height where D is maintained constant by increasing height.**

nc s d.b.h. or from higher in the stem of a larger tree. The data dis- us: l previously for yellow-poplar and red oak were analyzed to deter- nir whether d/D (or per cent bark volume) varied significantly with lei t in trees when diameter outside bark remained constant. In other 'or, the analysis was designed to answer the question of whether the er nt bark volume of bolts of a given diameter removed from near the ro d in small trees is significantly different than that of bolts of the an diameter removed from near the tops of larger trees.

he procedure consisted of selecting a given value of D (values ele d ranged from 4 to 13 inches in 1-inch increments) and segregating l/I alues according to height among trees at which the particular value f I occurred. The results are shown graphically for representative dia- net s in Figure 5. The results of tests of significance of the effect of eig t in tree on d/D for the individual diameters investigated are shown n ble 6.

eference to Figure 5 and/or Table 6 indicates that the effect of eig above 4.5 feet on bark volume of red oak bolts of a given diameter is

TABLE 6

**Results of tests of significance of effect of height in tree on d D different values of D.**

| Diam. bark outside | Species | |
|---|---|---|
| | Yellow-poplar | Red oak |
| 4 | N.S.+ | N.S. |
| 5 | ••++ | N.S. |
| 6 | •• | N.S. |
| 7 | •• | •• |
| 8 | N.S. | N.S. |
| 9 | •x | N.S. |
| 10 | N.S. | • |
| 11 | • | N.S. |
| 12 | N.S. | N.S. |
| 13 | N.S. | N.S. |

+ Not significant
++ Significant at 1% level.
x Significant at 5% level.

small. This was anticipated since, as discussed in the previous secti d/D values at given heights were not materially affected by d.b.h. In a tion, the effect of height above 16 feet on d/D values within d.b.h. cl. was of little consequence.

The effect of height on d D, where D was held constant, was stat cally significant for most diameters up to 8 inches in yellow-poplar (T 6). The effect of height was essentially the same as that found wi d.b.h. classes, being greatest in the smallest trees.

# Summary and Conclusions

Patterns of variation in per cent bark volume within and bet trees of the two major species investigated, yellow-poplar and red oak summarized in Figures 6 and 7 respectively. The values shown obtained by averaging mean d D ratios among which no significant ferences occurred and converting to per cent bark volume.

For the species investigated, the following points are apparent:

1. Per cent bark volume of red maple is essentially constant rega of tree size or position within tree.
2. In yellow-poplar and the oak species investigated, per cent bark ume varies inversely with height in trees 8-10 inches d.b.h. and sm
3. In trees larger than 8-10 inches d.b.h., the variation in per cent volume with height within d.b.h. classes is too small to be of prac concern.

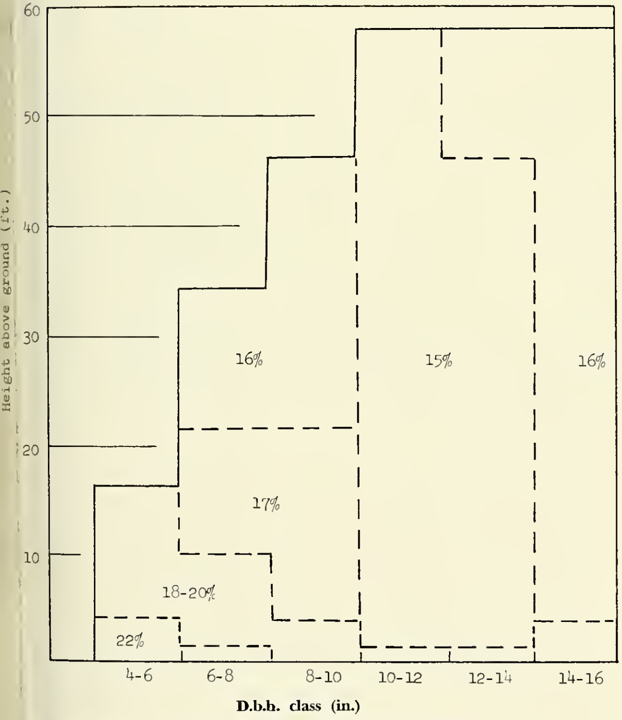


Fig : 6. **Variation in per cent bark volume in yellow poplar trees.**

4. n trees larger than 6-8 inches d.b.h., variation in per cent bark volume ith d.b.h. at all heights is negligible.

5. he effect of location of red oak bolts of a given diameter within and etween trees on per cent bark volume is not practically significant. he bark volume of yellow-poplar bolts of a given diameter will be reater if they are removed from the butts of small trees rather than om the tops of larger trees.

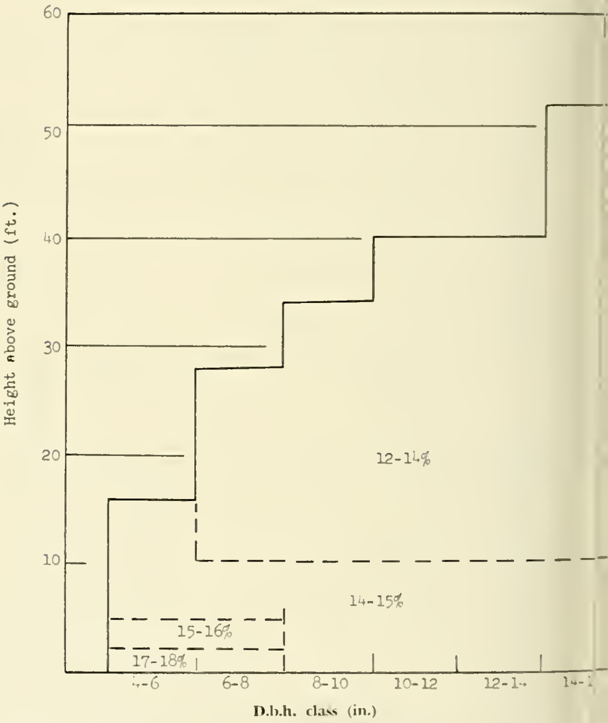


Figure 7. Variation in per cent bark volume in red oak trees.

6. Because of the present low value of hardwood bark, it is dou[bt]ful whether variation in bark volume within-and between-trees nee[d b]e given consideration in volume estimation. Average values w[hich] may be multiplied by total cubic foot volumes to provide a[...] volumes of sufficient practical accuracy are given below:

| Species | $V_B/V_T$ |
|---|---|
| Yellow-poplar | 0.17 |
| Red oak and black oak | 0.14 |
| Scarlet oak | 0.1? |
| Red maple | 0.08 |

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# APPENDIX

## Mean d/D values for height-d.b.h. combinations.

### TABLE I

**Mean d/D values for different height-d.b.h. combinations in yellow-poplar at Coopers Rock.**

| Hg above ground (feet) | 4-6 | 6-8 | 8-10 | 10-12 | 12-14 | 14-16 | Mean |
|---|---|---|---|---|---|---|---|
| | | | D.b.h. class (inches) | | | | |
| 3 | | | | .920 | .915 | .916 | .917 |
| 2 | | | | .922 | .919 | .914 | .918 |
| 5 | | | .922 | .923 | .916 | .914 | .919 |
| ) | | | .916 | .925 | .919 | .919 | .920 |
| 4 | | .923 | .916 | .923 | .921 | .916 | .920 |
| 3 | | .918 | .917 | .921 | .921 | .917 | .919 |
| 2 | | .911 | .914 | .922 | .923 | .917 | .917 |
| 5 | .899 | .910 | .911 | .921 | .921 | .916 | .913 |
| ) | .894 | .903 | .910 | .920 | .920 | .911 | .910 |
| 4.5 | .881 | .893 | .905 | .913 | .919 | .903 | .902 |
| 1.5 | .875 | .883 | .897 | .911 | .901 | .905 | .895 |
| Mean | .887 | .906 | .912 | .920 | .918 | .913 | .912 |

### TABLE II

**Mean d/D values for different height-d.b.h. combinations in red oak at Coopers Rock.**

| Hgt above ground (feet) | 4-6 | 6-8 | 8-10 | 10-12 | 12-14 | 14-16 | Mean |
|---|---|---|---|---|---|---|---|
| | | | D.b.h. class (inches) | | | | |
| | | | | | | .934 | .934 |
| | | | | | | .937 | .937 |
| | | | | .934 | .932 | .935 | .934 |
| | | | .922 | .937 | .926 | .934 | .930 |
| | | .935 | .930 | .938 | .932 | .936 | .934 |
| | | .933 | .925 | .937 | .929 | .939 | .933 |
| | .930 | .934 | .923 | .937 | .922 | .936 | .930 |
| | .927 | .931 | .922 | .931 | .926 | .938 | .929 |
| .5 | .919 | .919 | .920 | .928 | .923 | .935 | .924 |
| .5 | .911 | .906 | .909 | .929 | .920 | .933 | .918 |
| Mean | .922 | .926 | .922 | .934 | .926 | .936 | .929 |

## TABLE III

**Mean d D values for different height-d.b.h. combinations in black oak at Coopers Rock.**

| Hgt. above ground (feet) | D.b.h. class (inches) | | | |
|---|---|---|---|---|
| | 4-6 | 8-10 | 12-14 | Mean |
| 34 | | .930 | .934 | .932 |
| 28 | | .936 | .935 | .936 |
| 22 | | .936 | .937 | .936 |
| 16 | .937 | .934 | .932 | .934 |
| 10 | .932 | .930 | .934 | .932 |
| 4.5 | .910 | .911 | .926 | .916 |
| 1.5 | .896 | .914 | .926 | .912 |
| Mean | .919 | .927 | .932 | .927 |

## TABLE IV

**Mean d D values for different height-d.b.h. combinations in scarlet oak at Coopers Rock.**

| Hgt. above ground (feet) | D.b.h. class (inches) | | | |
|---|---|---|---|---|
| | 4-6 | 8-10 | 12-14 | Mean |
| 40 | | | .940 | .940 |
| 34 | | .934 | .942 | .938 |
| 28 | | .929 | .950 | .940 |
| 22 | | .941 | .944 | .942 |
| 16 | .944 | .940 | .944 | .943 |
| 10 | .929 | .932 | .944 | .935 |
| 4.5 | .911 | .928 | .942 | .927 |
| 1.5 | .898 | .925 | .938 | .920 |
| Mean | .920 | .933 | .943 | .934 |

## TABLE V

**Mean d D values for different height-d.b.h. combinations in red maple at Coopers Rock.**

| Hgt. above ground (feet) | D.b.h. class (inches) | | | |
|---|---|---|---|---|
| | 4-6 | 8-10 | 12-14 | Mean |
| 46 | | .950 | .950 | .950 |
| 40 | | .954 | .956 | .955 |
| 34 | | .960 | .954 | .957 |
| 28 | | .956 | .961 | .958 |
| 22 | | .960 | .960 | .960 |
| 16 | .959 | .962 | .963 | .961 |
| 10 | .957 | .967 | .961 | .962 |
| 4.5 | .959 | .962 | .959 | .960 |
| 1.5 | .954 | .958 | .961 | .958 |
| Mean | .957 | .959 | .958 | .958 |